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DeLeeuw, Jeffrey J.

Monterey, California. Naval Postgraduate School

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THESIS

IDEAL SYSTEM CAPACITY AND DEMAND MANAGEMENT FOR THE NAVAL TELECOMMUNICATIONS SYSTEM: AN ECONOMIC APPROACH

by

Jeffrey J. DeLeeuw

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Thesis Advisor: William Gates

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The Naval Telecommunications System (NTS) capacity to handle message traffic is frequency exceeded by high levels of user demand often resulting in a failure to meet message speed of delivery standards. In order to resolve this problem, managers of the NTS must decide to either expand system capacity, control demand, or apply some combination of these two alternatives.

The purpose of this thesis is to analyze this situation and make recommendations based upon the application of economic theory. The principles leading to the definition and understanding of optimal system capacity and user demand are laid out as they apply to the NTS. Having established a theoretical rationale for defining the ideal system capacity, a number of significant practical barriers to the implementation of this approach are explored. These barriers can be characterized as deriving from the

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tremendous difficulties encountered in the attempt to quantify cost and demand parameters necessary for determining the actual level of optimal system capacity.

Although a straightforward method of applying the relevant economic principles cannot be found, the theories discussed are of practical use, nevertheless, in that they predict a situation wherein the application of demand reduction techniques would be appropriate. This situation arises out of the fact that current NTS practices impose negligible costs upon users of the system. This in turn can be predicted to result in high levels of user demand with many of the messages serviced being of relatively low value. The results of a judgmental survey carried out on both Naval telecommunications and fleet operations personnel provide a preliminary confirmation of these conclusions. The recommendation is then made to implement some type of demand management scheme.

A review of available demand management tools is made leading to the final recommendation that some form of demand based pricing strategy, incorporating elements of both priority and peak load pricing methods, should be adopted.

One major objection to the efficacy of pricing techniques is addressed by way of reference to the Naval fuel allocation system and its effectiveness as a means of managing demand for fuel. Lastly, areas requiring significant further study pertaining to demand management and pricing methods are outlined.

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Ideal System Capacity and Demand Control for the Naval Telecommunications System: An Economic Analysis

by

Jeffrey J. DeLeeuw
Lieutenant, United States Navy
B.A., University of Illinois, Urbana, 1979

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Author: [redacted]
Jeffrey J. DeLeeuw

Approved by: [redacted]
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[redacted]
Dan C. Boger, Second Reader

[redacted]
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ABSTRACT

The Naval Telecommunications System (NTS) capacity to handle message traffic is frequently exceeded by high levels of user demand often resulting in a failure to meet message speed of delivery standards. In order to resolve this problem, managers of the NTS must decide to either expand system capacity, control demand, or apply some combination of these two alternatives.

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Although a straightforward method of applying the relevant economic principles cannot be found, the theories discussed are of practical use, nevertheless, in that they predict a situation wherein the application of demand reduction techniques would be appropriate. This situation arises out

of the fact that current NTS practices impose negligible costs upon users of the system. This in turn can be predicted to result in high levels of user demand with many of the messages serviced being of relatively low value. The results of a judgmental survey carried out on both Naval telecommunications and fleet operations personnel provide a preliminary confirmation of these conclusions. The recommendation is then made to implement some type of demand management scheme.

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I. INTRODUCTION

A. BACKGROUND

The Naval Telecommunications System (NTS) capacity to handle message traffic is frequently exceeded by high levels of user demand. This often results in message backlogs and failure to meet established speed of delivery standards. In order to resolve this problem, managers of the NTS must decide to either expand system capacity (capital investment), control demand, or apply some combination of these two alternatives.

B. OBJECTIVES AND RESEARCH QUESTIONS

The purpose of this thesis is to analyze the problem faced by the NTS with respect to excess demand in order to make recommendations towards resolving the problem. Recommendations are made in terms of defining and achieving the appropriate mix of demand management and/or capital investment techniques. Economic theory is applied as a means of providing analytical tools which are useful in gaining a more precise understanding of the nature of this problem and its solution.

The following specific questions are addressed:

- How is this situation explained using basic economic principles?
- How is ideal system capacity defined?

- Can the theoretical model of ideal system capacity be applied to the NTS?
- Are the barriers to straightforward application of the economic model surmountable? If so, in what way?
- What is the appropriate level of demand management and/or capital expansion to solve the NTS excess demand problem?

C. SCOPE AND LIMITATIONS

This thesis is an attempt to apply basic economic theory to problems of excess demand currently faced by the NTS. Questions concerning the practical application of economic principles from the viewpoint of a NTS manager are given particular emphasis.

A great deal of effort and analysis towards defining and quantifying the extent of demand outstripping NTS capacity will not be invested. Reference is made to previous work which outlines this information in greater detail. This work will briefly sketch the nature and significance of this problem in order to serve as a starting point for further analysis which comprises the main thrust of this thesis.

A recommendation to reduce system demand via implementation of a demand management mechanism is made, followed by a brief review of applicable methods. Several major objections to instituting this type of solution are discussed.

Implementing any type of demand management method in order to obtain a specific goal is a complicated task. This thesis only goes so far as making broad recommendations. Additional questions and areas requiring significant further study are outlined.

D. ORGANIZATION OF STUDY

Problem definition is followed by explanation and discussion of economic principles used to define the concept of ideal long run system capacity. From the point of view of a NTS senior manager, barriers to the direct application of this concept are explored.

Upon concluding that direct application of the economic concept of ideal system capacity is impractical, information previously presented is reviewed with an eye towards finding information which might yet prove to be of practical use. Observations concerning excess demand and the relative value of messages entered into the NTS are forwarded. These conclusions are informally tested for validity by use of a judgmental survey of a select group of Naval personnel.

The recommendation that a demand management strategy be pursued is followed by a brief review of available pricing strategies. Broad recommendations concerning the type of pricing mechanism best suited to the NTS are made, followed by a discussion of potential shortcomings involved in the pursuit of a pricing strategy.

Lastly, information, conclusions, and recommendations are reviewed along with a brief listing of areas requiring further study.

II. PROBLEM DEFINITION

A. INTRODUCTION

The NTS is faced with making critical management decisions concerning the system's ability to cope with user demand for services. This chapter will outline the facts concerning excess demand, provide a definition of the problem in economic terms, and review the broad alternatives available to management in dealing with this problem.

B. DEMAND EXCEEDS SYSTEM CAPACITY

What is meant by demand outstripping capacity? Demand is defined as, "...a list of prices and the corresponding quantities that consumers are willing and able to purchase..." [Ref. 1:p. 22] Capacity, or available supply, is defined as, "...a list of prices and the corresponding quantities that a group of suppliers (firms) would be willing and able to offer for sale at each price..." [Ref. 1:p. 30] In a market economy, an equilibrium point between supply and demand occurs where the quantity demanded at a particular price equals the quantity supplied at that price. This relationship is illustrated by Figure 1.

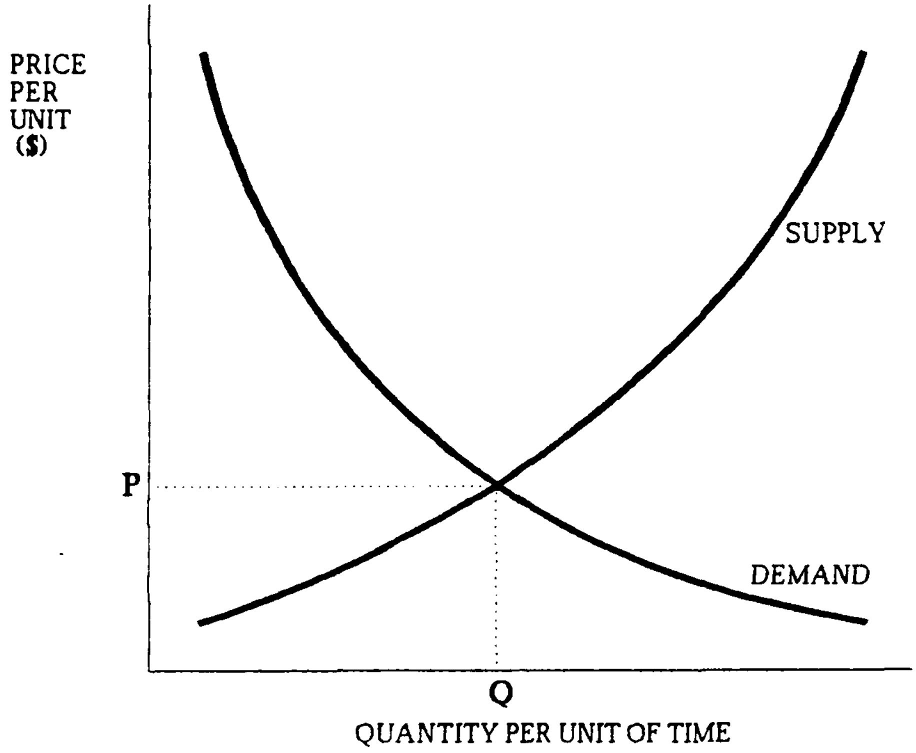

Figure 1. Supply and Demand Equilibrium

The relationship between supply and demand for the NTS differs from this simple model in several ways. The NTS does not presently charge users for the provision of its services. The NTS is willing and able to deliver any number of messages up to full system capacity. Capacity is determined primarily by the throughput limits of existing hardware, therefore, the NTS could not exceed this capacity in the short run regardless of price. This relationship is represented by a vertical (or near vertical) supply curve rising from the quantity representing system capacity.

With respect to user demand, users will demand service as long as the value of their message exceeds their cost of using the system. There will be a small class of messages whose value is extremely high (e.g., warnings of imminent attack, nuclear accidents, etc.) so that their transmission would be requested regardless of price. Apart from this small class of high value messages (where the slope of the demand curve for this class is nearly vertical), the rest of the demand curve would be downward sloping in that as the price to the user decreases, an increasing quantity of message services will be requested.

Current price to the user consists primarily of opportunity costs (i.e., how the time spent in the activity of generating a message might have otherwise been spent), along with relatively minor material costs such as paper and sundry office supplies. The important point is that the actual cost to the user does not include any type of charge for services by the supplier and that the opportunity costs themselves are quite low.

In this context, demand outstripping supply means that the quantity of services demanded at the present price to the user (opportunity costs) is beyond NTS capacity as shown in Figure 2.

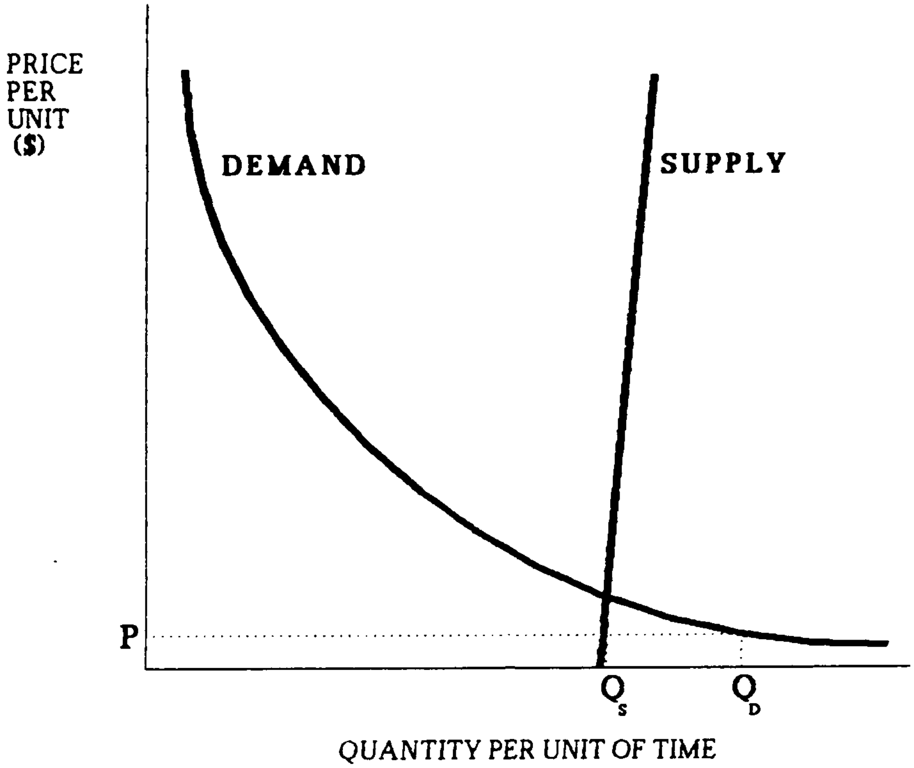

Figure 2. Excess Demand

Without going into great detail, one empirical measure that might be employed to document this excess demand focuses on NTS speed of delivery standards, i.e., excessive delay represented by exceeding message precedence time standards can be equated with demand for service exceeding NTS capacity. In one twelve-day period, a total of 4,493 messages were keyed over the general Fleet Broadcast. Of these, a total of 787, or 18%, failed to meet speed of delivery standards as measured from time of receipt from originator to the time the message was actually keyed on the broadcast. On the worst day, a

total of 100 out of 324 messages exceeded speed of delivery standards, 94 of these being Immediate precedence or greater. [Ref. 2:pp. 20-22]

C. MANAGEMENT OPTIONS

In the face of excess demand, the general decision categories facing NTS managers are as follows:

- reduce demand for NTS services
- increase system capacity
- incorporate elements of both demand reduction and system expansion

What is of particular interest to us here is not what these various schemes might be, but rather, on what basis should management decide to pursue one course of action over the other?

Upon closer examination, the decisions which must be made exist in two dimensions; short run and long run. Note that the outstripping of supply by demand described above is a short run situation (i.e., it refers to an output which is calculated on the basis of current fixed material assets). What is of primary interest is the managerial decision with respect to long run considerations.

By definition, the "short run" is a period of time wherein at least one of the inputs to the production equation is fixed. The "long run", on the other hand, is the period of time in which all inputs are considered variable. [Ref. 3:pp.

229-230] In the short run, new technology cannot be incorporated into the fleet which might increase total message throughput capacity. In the long run, all factors affecting capacity are considered variable, including any and all technologies, encoding methods, and respective equipment quantities which might increase total NTS capacity.[1] In the short run, there really is no decision for management to make other than how to manipulate demand so as to relieve the existing bottleneck. The method chosen should result in the NTS being used as efficiently as possible, i.e., reducing demand in such a way that those messages excluded from the system are those which are of least value.

The larger decision, the long run decision faced by NTS management, is a type of unconstrained optimization problem, i.e., how can the maximum benefit of services provided by the NTS to the Navy be realized? What level of service is optimum? Once having derived that information, and considering all inputs variable, what is the optimal combination of inputs necessary to produce it?

If the optimum level of service is found to be at or less than current system capacity, then demand reduction is clearly indicated. If the optimum level is greater than current capacity but less than current demand, then a combination of

---

[1] A more precise definition of the short run, long run time periods and their significance is found in Chapter 3.

system expansion and demand reduction is warranted. Lastly, if optimal capacity is found to lie at a level exceeding current user demand, then system expansion is in order.

The central challenge then, is to define and locate the optimal long run level of system capacity in order to provide a basis for making management decisions. It is the theoretical approach to meeting this challenge with which this thesis concerns itself.

III. IDEAL CAPACITY

A. INTRODUCTION

Economic theory provides a model of ideal system capacity based upon a balance of system costs and benefits. This chapter introduces terms, definitions, and concepts necessary to understand the notion of ideal system capacity, the optimum combination of inputs to produce this capacity, and how this applies to the NTS.

B. MARGINAL REVENUE AND MARGINAL COST

The solution to the problem concerning an optimal level of system service and the optimum combination of inputs necessary to produce it is found by reference to defining and maintaining a balance between system costs and benefits. Simply put, "a firm will increase any activity so long as the additional revenue from the increased activity exceeds the additional cost of the increase in the activity." [Ref. 1: p. 52]

Several definitions are required at this point, in order to proceed with a more thorough elaboration of this concept.

- Marginal revenue (MR): change in revenue per unit change in output. [Ref 3:p. 268]
- Marginal cost (MC): additional cost per unit increase in output. [Ref 3:p. 227]

- Average cost (AC): mean cost per unit. [Ref 3:p. 236]

The above-mentioned costs may also be grouped according to the previous distinction made between the short and long run time intervals.

- Short run (SR): period of time in which the firm must consider some of its inputs to be fixed.
- Long run (LR): period of time over which all inputs are treated as variable.

These terms are used to identify different periods of time in which a firm may alter its production decisions. [Ref 3: pp. 229-230] For example, short run production decisions are made within the constraints imposed by fixed plant size, this being an element which cannot be altered on short notice. Long run production decisions, on the other hand, are unconstrained with respect to plant size since over long periods of time all input components may be varied.

In terms of MR and MC, the optimization principle can be restated as follows: a firm will select that level of output where MR equals MC. [Ref 4:p. 47] This level of output is shown by Q_{Profit} in Figure 3. This is the level of output where the revenue realized from selling one additional unit equals the additional cost of having produced it. The reasoning behind this principle makes intuitive sense and can be applied to the NTS with the incorporation of one significant modification.

C. MARGINAL UTILITY

Marginal revenue is only important to a firm seeking to maximize profit. The NTS goal is maximum benefit (utility) to the Navy, not profit. The point we are interested in defining is where the marginal benefit (i.e., marginal utility) of a naval message equals marginal cost. This is the point where the utility gained from the transmission of one additional message equals the cost of having transmitted that additional message. More specifically, this is the point where marginal utility (MU) equals long run marginal cost (LRMC). Their point of intersection will define the optimal production quantity where marginal benefits and costs are in equilibrium, as shown by $Q_{Utility}$ in Figure 3. [Ref 4:pp. 75-76]

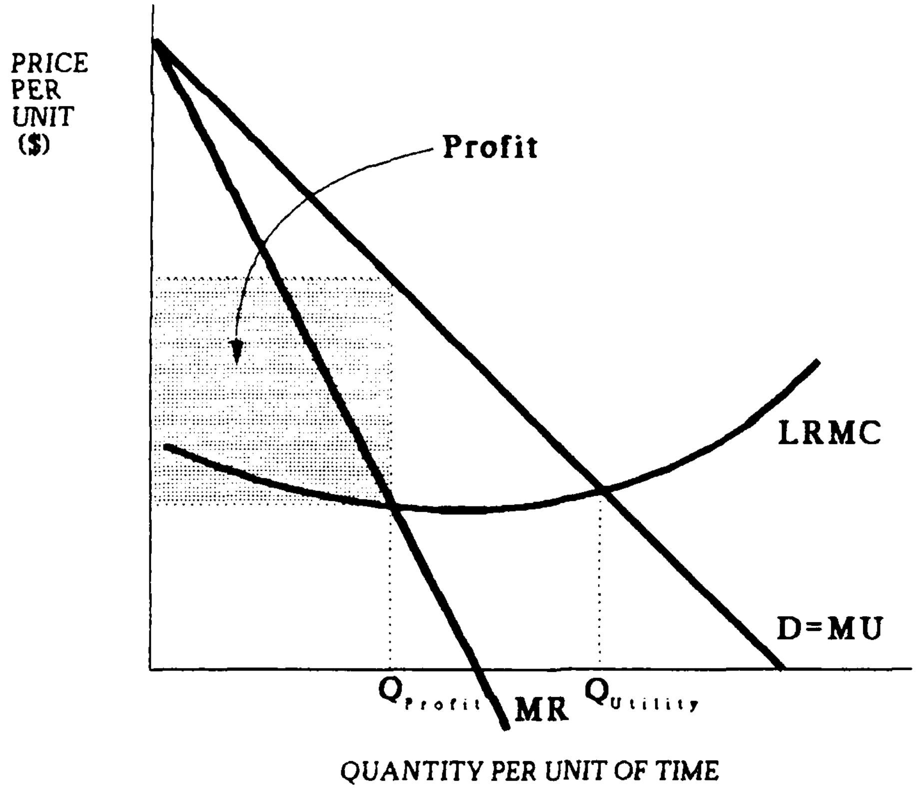

Figure 3. Factors Determining Production Quantity Optimization

How does one measure the utility of a naval message? As with any good or service, the utility cannot be measured directly but is measured indirectly in terms of how much one is willing to give up for it. For naval messages then, the number of messages whose utility is greater than or equal to the actual cost of sending a message will represent the total quantity of service demanded. This is simply another way to describe the relationships which underlie the demand curve and its particular shape. The demand curve represents the marginal utility (MU) curve for naval messages; that is, D = MU. More will be said concerning the actual shape of this curve later.[2]

D. OPTIMUM CAPACITY

To find the level of service (Q) where optimum benefit to the Navy is realized, we must find the point where LRMC equals demand. The optimal quantity of services provided by the NTS (Q^*) will be defined by the point where the LRMC curve intersects the demand curve (LRMC = D) as shown in Figure 4.

[2] With the previous discussion of the current "price" of a naval message in mind, it should not be surprising that high demand levels are observed, and that the utility of a great many of these messages would be expected to be quite low.

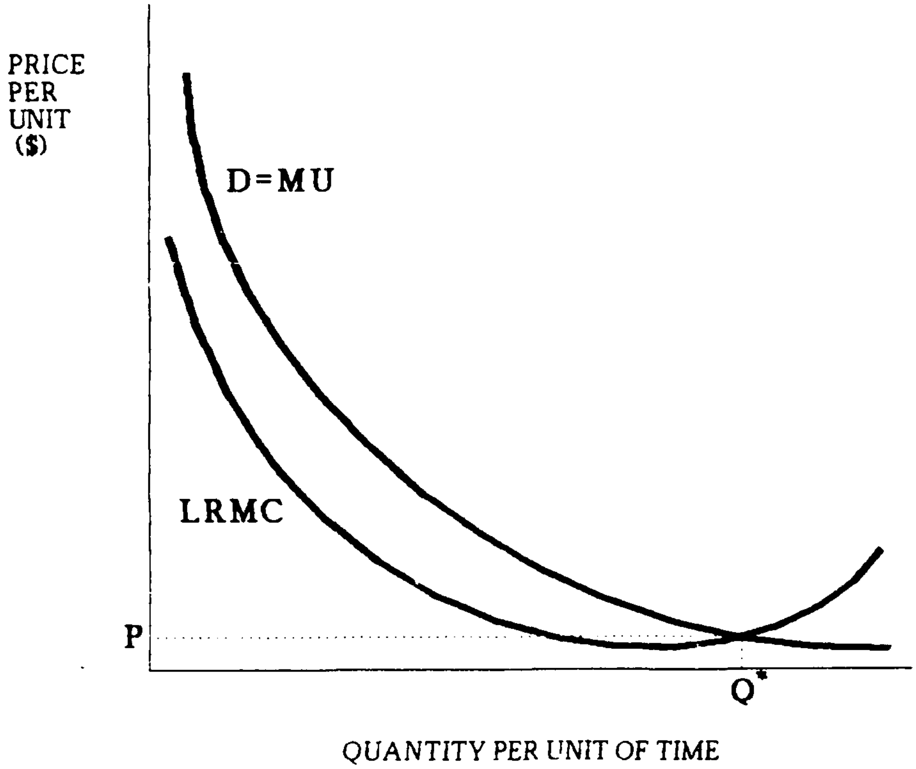

Figure 4. Optimal Production Quantity (Q*)

If the point where LRMC = D is less than the present level of system capacity, then NTS managers should direct their efforts towards reducing system capacity and constraining demand through appropriate demand management policies. If that point is found to lie beyond the present level, then NTS managers should seek to expand capacity in the long run, although demand management policies may be required to restrict demand within system capacity in the short run. The goal is to operate where LRMC = D.

To make the proper long run decision, two categories of long run cost must become known: Long Run Marginal Cost (LRMC) and Long Run Average Cost (LRAC). The central role

of LRMC with respect to defining Q^* has been outlined. In order to make our analysis complete we are ultimately concerned with the most efficient combination of inputs in the short run which will allow the NTS to operate at that optimal level (Q^*) defined by the long run planning curves. The LRAC curve provides the data which can be utilized to logically translate long run ideal capacity to a specific short run system configuration. An organization plans in the long run but operates in the short run. [Ref 1:p. 295]

E. OPTIMUM INPUTS

At each possible level of output there is a corresponding least cost combination of inputs. Each set of least cost inputs can be associated with a coinciding set of short run marginal cost (SRMC) and short run average cost (SRAC) curves unique to that particular, discrete output quantity (Q). Knowing these least cost combinations of inputs, we can derive the LRMC and LRAC curves. The relationship between the SRAC curves and the LRAC curve is that any particular SRAC curve will be tangent but always above, the LRAC curve at the Q which represents the optimal combination of inputs necessary to produce it. In other words, the LRAC curve consists of the locus of points representing the lowest possible short run average cost of producing the corresponding output. By definition, for that Q, the LRMC curve must also equal the corresponding SRMC curve derived from that same optimal

combination of inputs, as illustrated in Figure 5. [Ref. 1:pp. 295-297] Note that for Q^* (the output level which maximizes the value of the system), the following relationships hold:

- LRMC = D
- LRMC = SRMC (associated with the least cost input combination)
- LRAC = SRAC

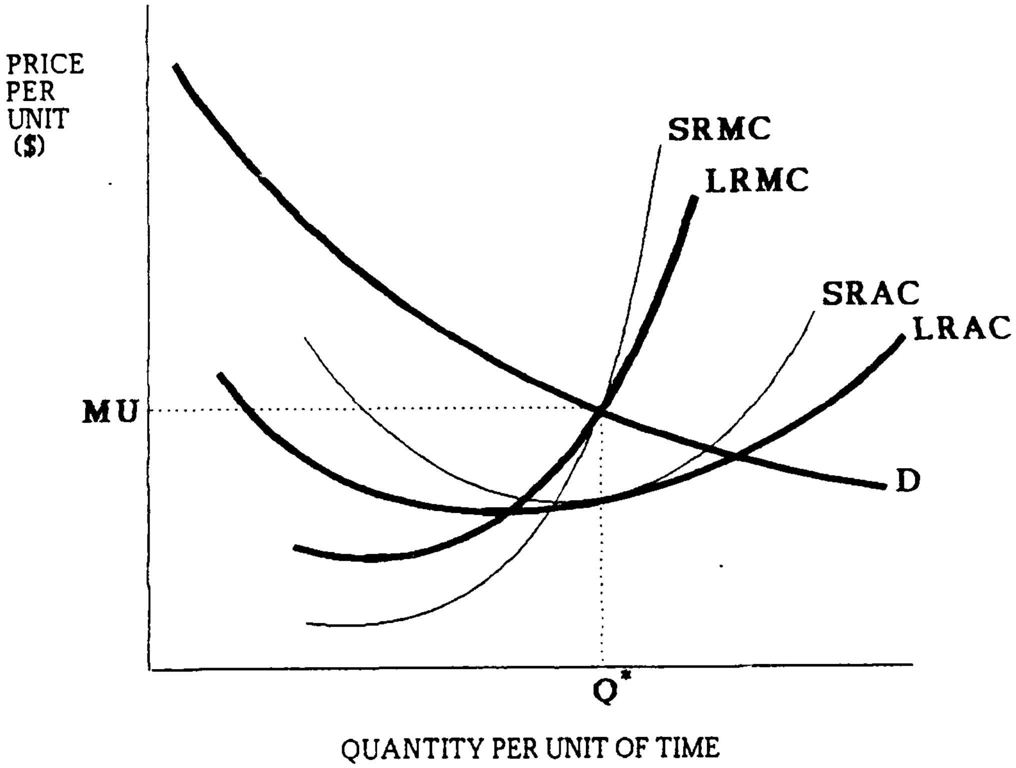

Figure 5. Relationship Between Long Run and Short Run Cost Curves

In other words, the procedure is as follows:

1. Find the desired output level, Q.

2. The lowest cost for producing Q is given by the point on the LRAC curve corresponding to Q.

3. Find the SRAC curve tangential to the LRAC curve at this point. This SRAC curve defines the lowest cost combination of inputs necessary to operate at the desired output level Q.

F. OVERVIEW

At this point, an overview of the problem and the suggested method of solution might serve to bring things into sharper focus. We are dealing with an unconstrained optimization problem involving the combination of inputs required by the NTS to produce the greatest benefit to the Navy. The optimal level of output is defined by that point where LRMC = D. Having defined the optimum production level Q^*, the optimal set of production inputs necessary to produce Q^* must next be defined. (Plan in the long run, operate in the short run.)

Using the relationship between long run and short run costs we are able to translate Q^* into a concrete set of optimal short run inputs. Realizing this output level Q, and the inputs necessary to attain it, becomes the task of NTS management. Application of this model to the choices faced by NTS management promises that the capacity choice decision will have been arrived at through the application of sound economic principles.

IV. IMPLEMENTATION BARRIERS

A. INTRODUCTION

This chapter explores the practical difficulties encountered when attempting to apply the theoretical approach to finding optimum long run capacity (described in Chapter III) to the NTS. The extensive and serious nature of these difficulties is such that implementation of the aforementioned theory is concluded to be impractical.

B. DIFFICULTIES IN DEFINING COST

In order to find Q^* for the NTS, the LRMC and LRAC curves must be defined. Both curves, in turn, are derived from a series of SRMC and SRAC curves representing the most efficient short run combination of inputs for all given output levels Q. Finding Q^*, therefore, requires quantifying the optimal SRMC and SRAC curves corresponding to a representative sample of long run output levels.

Several additional terms require definition before proceeding with this analysis.

- Fixed Cost (FC): input cost which remains constant in the short run regardless of output level. [Ref. 1:p. 271]
- Variable Cost (VC): input cost which varies in the short run as a function of output level. [Ref. 1:p.

271]

- Total Cost (TC): the sum of fixed and variable costs.
- Direct Cost: a cost that can be obviously and physically traced to the particular segment under consideration. [Ref. 5:p. 43]
- Indirect Cost: a cost that must be allocated in order to be assigned to the segment under consideration. [Ref. 5:p. 44]

The process of quantifying the costs making up the SRMC and SRAC curves is extremely complex and requires the application of several subjective judgments. All fixed and variable costs must be accounted for because SRAC is a function of TC divided by Q, and SRMC is defined as the change in VC per change in Q. In order to realize the difficulties encountered in this procedure let us consider as an example what might be involved in quantifying these costs for existing NTS capacity.

First, consider the scale of this undertaking. The NTS is comprised of literally hundreds of shore facilities spread out across the globe. Every ship and submarine also carries gear and personnel onboard dedicated to sending and receiving message traffic and therefore must be included in any measure of system cost. The total cost of providing message traffic service, separated into fixed and variable cost categories, must be calculated for each and every one of these elements. The accounting mechanism and procedures for providing this

data do not exist. Even if averages and cost models were used instead of relying on actual dollar figures, the task would still constitute an enormous undertaking.

Second, consider the complexity involved in determining costs. The NTS does not rely on a single means of transmitting message traffic. Numerous propagation paths are used, such as satellite, various portions of the electromagnetic spectrum, and land lines.[3] Satellites and land line modes of communication are not dedicated to providing NTS service alone, but rather are shared for different purposes by different agencies. [Ref 6:pp. 7-19] The exact mix of shared services will vary from one land line trunk to another and from one satellite to another. Determining the NTS' share of costs would require looking at each shared leg of the system individually, and then deciding how the direct costs should be allocated. Should the allocation of costs be based on relative share of volume, or should it consider the importance (i.e., value) of the information carried, and if so, how should this be done? The point is that final cost figures which result from such decisions involve more than simply adding up columns of figures, particularly if average costs increase or decrease as capacity of a shared system increases. The extent to which

[3] Characterizing the means of transmission in this manner is an obvious over-simplification, but for the purposes of this discussion these three means will be used to avoid adding unnecessary complexity.

the judgments invoked in allocating shared direct costs might be challenged calls into question the resulting cost figures.

Third, to further complicate the above mentioned cost measurement difficulties, add the additional level of complexity represented by indirect costs. The problem with respect to indirect costs is two-fold. First, all indirect costs must be catalogued, and second, a means for their allocation must be agreed upon.

For a given communications facility the direct costs, such as electricity to power the equipment and paper on which to print messages, are relatively easy to identify and quantify. Each of these costs stems directly from providing message service. Indirect costs are much harder to list, let alone assign the proper cost levels. Indirect costs include things such as providing a guard at the base gate, street and building maintenance, food service, welfare and recreation, etc. Recognizing that it takes more than an antenna, a transmitter, and a teletype terminal to provide message service is not difficult. Listing the elements included in "more" is difficult.

Even if all the indirect inputs were listed, the problem would still remain as to how their respective costs should be allocated. The gate guard provides service for the entire base. How much of this expense should be applied to the NTS? What basis should be used to make this decision? Number of personnel? Size of the building? Perhaps since a

communications station's security is more important than the base laundromat's, a greater share of cost should be assigned to it. Similar questions arise with respect to each category of indirect cost. Consider air conditioning for a shared building. How much of this expense goes to NTS? Perhaps the NTS facility occupies only a small part of the building but the provision of reliable air conditioning (for electronic gear) is more important to it than any of the other facilities.

Consider the number of indirect costs, multiply this by the number of elements in the NTS, and include these sorts of questions when dealing with shared communications paths. Once again, the actual cost amounts will be contingent upon judgments concerning cost allocations which are anything but clear cut. The extent to which these judgments might be questioned reflects directly on the reliability of the figures produced.

The discussion to this point has concerned itself with the difficulties inherent in finding costs for the existing NTS. The task at hand is much more difficult in that cost figures (with the attendant difficulties mentioned above) are needed not only for present capacity, but also for a representative sampling across the entire range of long run capacities, each set of cost figures aiming to represent the most efficient combination of inputs possible. By definition this means that relevant existing and proposed communications technologies

would have to be critically evaluated. The relative efficiency of each, in combination with the others, at selected output levels, would have to be projected.[4]

The point to be made is not that the cost measuring process is *impossible,* but that the task is enormous in scale, and that currently no accounting system is in place that could even begin to provide the necessary data.

C. DIFFICULTIES IN DEFINING DEMAND

The demand curve for NTS services is used to correlate Naval messages and their respective utility, i.e., usefulness. The shape of the curve is a function of the change in marginal utility per unit change in output, i.e. number of messages. How does one quantify the value of a message? For that matter, how is value assigned to any good or service? The value of a good or service is best defined in terms of what one would be willing to give up to obtain it, the common denominator between goods and services being currency. In other words, the value of something becomes what one would be willing to pay for it.

This approach works well with respect to quantifying demand for goods traded openly in the marketplace. Information concerning the relationship between value of a

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[4]A representative sample of output levels separated by designated intervals could be selected for evaluation; therefore, doing away with the need for evaluation of all output levels, and greatly simplifying the process. The process remaining, however, would still be far from simple.

good and quantities demanded at each value level is readily observable, if not directly, then through test markets, surveys, etc.

How might this same information be obtained for Naval messages within the NTS? Since the service carries no charge whatsoever, and never has, demand versus price data is non-existent.

Certainly some messages carry more value than others. How is this value to be measured, and how can the number of messages per value level be determined? It appears doubtful that survey results could yield data with a sufficient degree of reliability. Establishing a test market would introduce a great many artificialities with respect to the NTS, therefore, rendering the results obtained less than optimal. Perhaps an analysis of large volumes of traffic could be conducted by expert Naval personnel to assign values and determine quantities for each value. Results obtained in this manner would always remain questionable, however, due to an obvious heavy reliance on the subjective judgments of the personnel involved. "Given the difficulty in applying all of the formal methods of valuing information, managers are in most cases left no alternative but to rely on subjective evaluation." [Ref 4:p. 30]

D. CONCLUSION

Economic theory provides a sound framework for defining and understanding long run capacity planning. When applied

to the short run excess demand situation currently experienced by the NTS, a clear model whose elements serve to define optimal NTS capacity is provided. The clarity and logical elegance of the model is appealing, as is the promise of providing an objective means to formulate plans leading to optimization of NTS benefits to the Navy.

The problem lies in the difficulty of quantifying necessary components of the model with any degree of certainty. Significant barriers exist with respect to cost and demand elements, effectively blocking the straightforward application of theory to real world fact.

Since long run capacity planning is not a unique requirement of the NTS, we sought to find examples of how economic theory might have been applied by other organizations. In so doing we hoped to find information which might apply to the NTS. Unfortunately, what little was found reflected on the application of economic theory in a negative light. One study in particular stood out in that its goal was to determine whether institutional-level communications planners used economic concepts in their system planning procedures, and if so, how were they used? Ten core economic principles were identified including those concerned with cost-benefit analysis, fixed-variable costs, marginality, and system optimization. The study concluded that communication planners at the top management levels of an organization do not use economic concepts. Only limited evidence of

infrequent, implicit, and informal application of economic principles was found. The authors of that study make no conclusions regarding the reasons for this paucity of economic principle application, but raise the questions, "Is it that the data needed for formal analysis are not available or affordable? . . . That the concepts are not well-fitted to the problems that these planners deal with?" [Ref 7:pp. 308-317]

The conclusion drawn from the information and analysis presented up to this point is that the direct application of economic theory relating to long run capacity planning is not practical, at least in the short run, for the NTS.

V. PRACTICAL ALTERNATIVES

A. INTRODUCTION

Having established that direct application of the economic theories defining ideal long run system capacity are impractical, the purpose of this chapter is to explore the possibility of there being alternative applications of the economic principles previously described that might be of practical value to NTS managers. Recall that solving the problem of excess system demand in the long run might be dealt with in one of three basic ways: expand system capacity, reduce demand, or implement some combination of both.

The question then becomes, are there any conclusions that might be drawn from our previous discussion of economic principles which might provide at least partial information to be used in making a decision with respect to these alternatives?

B. COST, MARGINAL UTILITY, AND DEMAND LEVEL

Upon review of the elements which determine the level of user demand for NTS services it becomes immediately apparent that the current condition of excess demand over short run system capacity should come as no surprise.

Recall that current price to users is measured by opportunity costs. Opportunity costs are defined as, "...

potential benefit that is lost or sacrificed when the selection of one course of action makes it necessary to give up a competing course of action." [Ref. 5:p. 46] In other words, the cost incurred by the NTS user entering a message into the system consists basically of the sacrifice of those benefits that might have been gained had the time spent preparing a naval message been invested in some other task. Costs such as paper, ink, paper clips, etc., are so small as not to merit consideration as a potential influence on user behavior.

Although hard data quantifying the precise level of opportunity costs to the user does not exist (and in fact would be subject to many of the same barriers faced in gathering information on other types of cost) it does not require any great leap of faith to conclude that opportunity costs to drafters of naval messages are, for the most part, quite low.

Next consider those factors which are responsible for shaping user demand for NTS services. Recall the definition of demand previously given: "... a list of prices and the corresponding quantities that consumers are willing and able to purchase..." [Ref. 1:p. 22] Users will demand service so long as the value of their message exceeds or equals their cost of sending that message. The demand curve for the NTS illustrates this relationship.

The costs to users of the NTS, represented by opportunity costs, are extremely low. Users will demand service up to the point where the value of the message equals the cost of that message. Note that by "users" we mean those whom receive value from a message and, therefore, create a demand for NTS service. Value from a message may accrue to either senders or receivers. If it is the sender, then the only costs imposed are opportunity costs. If it is the receiver, then no costs are imposed. In either case, these relationships serve to explain why a high level of demand for NTS services is to be expected. Furthermore, we can also predict that a significant proportion of the messages constituting this demand will be of relatively low value, i.e., down to the point where their value equals the opportunity cost incurred in producing it.

C. JUDGMENTAL SURVEY

The fact that user demand is high underlies the initial assumptions of this thesis concerning excess demand over short run capacity. But what of the conclusion that a significant portion of messages constituting this demand are of relatively low value?

A judgmental survey of selected fleet personnel was undertaken to provide a qualified validation of this conclusion. A judgmental survey's results are contingent upon the surveyor's *judgment* with respect to population sample

selection, and survey results appraisal, hence the name. Judgmental surveys are inherently not subject to any form of statistical analysis. [Ref. 8:pp. 10-11] Use of a probability survey (which can be subjected to statistical analysis) would be problematical for exactly the same reasons listed to explain barriers to quantifying the NTS user demand curve. The task is the same in both cases since the NTS demand curve and marginal utility curve are one and the same. Results of this judgmental survey cannot provide any sort of quantifiable results, therefore, but rather they serve to provide a broad indication of the validity of the hypothesis.

The survey was conducted in the form of a series of informal telephone interviews with selected personnel assigned to both telecommunications and fleet operational billets. Telecommunications personnel would be familiar with the entire collection of messages sent, while individuals in operational billets would be in a unique position to assess the "value" of message traffic received to their daily operations. Respondents were initially asked whether all of the message traffic they received was of value to them in the execution of their command's mission. Subsequent questions were tailored to the exact nature of the response given to this question in an attempt to define broad categories of traffic whose value was stated to be zero or negligible. Aditional questions were aimed at having the respondents estimate the

percentages of message traffic falling into these lowest value categories. Survey results are reviewed in the following paragraphs. [Ref. 6]

Survey respondents were unanimous in their appraisal that a great many of the messages currently being handled by the NTS were of extremely low value. Value of message traffic was gauged in terms of its usefulness towards satisfying command missions on a daily basis. In other words, did it help them, or others, to do their jobs?

All respondents indicated that a significant percentage of the traffic they received would have little, or no significant impact on their job effectiveness had they not been received at all. Examples of messages frequently cited as belonging in this category include duplicate messages, messages received by virtue of Address Indicator Group (AIG) membership, and various other collectively addressed messages having no relevance to their particular unit. Estimates of the percentage of messages belonging in this category ranged from 50% to 10% of total volume received. These messages represent the lowest categories of message traffic value because they are irrelevant to the receiver. In that they are irrelevant to the receiver, they can hold no value for either sender or receiver.

Nearly all of the respondents indicated that while a significant portion of the remaining traffic they received was indeed valuable to their command, their receipt via the

electronic transmission channels provided by the NTS was unnecessary in that their content did not require the speed inherent in electrical transmission. Frequently cited examples of messages belonging in this category included official orders, promotion lists, certain types of intelligence reports, and numerous other message types which could be roughly grouped together under the heading of "administrative" messages. Estimates of the percentage of messages belonging to this class ranged from 50% to 20%.

With respect to this latter category of message traffic, respondents acknowledged the existence of official efforts to curtail entry of messages into the system not requiring electrical transmission [Ref. 10:pp. 1-3]. Messages not requiring the speed of service provided by electrical transmission are directed to be sent by alternate means. Survey respondents were unanimous in their evaluation that these efforts, to date, have had little or no effect.

We can broadly interpret these survey results as being supportive of the prediction that a significant portion of the message traffic handled by the NTS is of relatively low value. Furthermore, the survey indicates that a class of messages exists which are indeed valuable but need not necessarily be transmitted via the NTS. The unanswered question is whether the value of this latter class of messages exceeds the long run costs of expanding the NTS which might be incurred to support them.

D. INITIAL RECOMMENDATIONS

On the basis of these results what recommendations can be made? From among the management alternatives to expand system capacity, reduce demand, or combine some measure of expansion with demand reduction, we can conclude that the best alternative must at the very least include demand reduction to eliminate the lowest categories of message traffic. In other words, the alternative of expanding long run system capacity to handle the entire volume of user demand can be eliminated. Whether eliminating these lowest categories of traffic would be sufficient to bring system demand within short run capacity cannot be determined on the basis of the information at hand.

It is important to note that there is also a cost incurred by sorting out inappropriate addressees in collectively addressed messages and AIGs, i.e., the opportunity cost of the time necessary to accomplish this task. It might still be optimal to send these irrelevant messages if the cost of sorting them out exceeds the cost of sending them. This describes the current situation. Even if higher costs were attached to sending a Naval message, some irrelevant traffic would still persist. What we seek is not their total elimination at any cost, but rather, that senders be forced to consider the true costs involved before sending them. At present this is not the case, and hence, far more of them exist than should.

VI. PRICING METHODS

A. INTRODUCTION

Attaching prices to the service provided by the NTS is the most direct method available to control user demand. This chapter will provide an overview of the general categories of pricing methodologies and their most significant features. If the cost to the user is raised above current levels (consisting of opportunity costs alone), then only those messages whose value is equal to, or greater than, that cost will make up demand. NTS management should be aware of the unique characteristics inherent within each type of pricing scheme in order to evaluate whether this approach should be adopted to control demand. Any plan ultimately selected would require tailoring to adapt those features which would best shape user behavior in terms of the desired system demand levels.

B. GENERAL CONSIDERATIONS

The following general considerations apply to the selection of any pricing scheme [Ref. 11:pp. 102-104]:

- The problem of finding the best pricing system to achieve organizational goals is not merely an accounting question. The types of prices which will stimulate desired user behavior may have nothing to

do with allocation of actual system costs. A flat fee, with no relation to any sort of cost architecture whatsoever, might be as effective as the most complex cost based pricing system ever devised.

- The pricing scheme must be kept simple so as to render it understandable to the users. Systems based on standard costs per unit are typically seen and supported by users as being more equitable than a complex, confusing formula.
- It is important that the pricing scheme be viewed as fair and reasonable by the user.

C. COST-BASED PRICING

Cost-based pricing mechanisms set prices on the basis of costs incurred in providing the service. Several cost-based pricing mechanisms are currently in use.

1. Average Total Cost Pricing

Average total cost pricing simply sets price equal to the per unit average total cost of operation. This approach has the advantage of being relatively simple to implement (at least at first glance), and is easily understood by the user. The equilibrium between demand and supply maintained with marginal cost pricing is not a feature of average total cost pricing. With this method the supplier, however, is able to recover all costs associated with providing the service [Ref. 11:pp. 27-29].

Using this method, achieving a balance between supply and demand becomes nearly impossible owing to the complete focus on supplier costs while disregarding user demand. An illustration of what form this sort of imbalance might take can be found by referring to a hypothetical computer center which decides to base computer access charges on average costs of maintaining the center. If this average cost based price corresponds to a level of user demand lower than the current level, then demand will fall off. This in turn will raise average costs, boosting prices, leading to another reduction in user demand, etc. The end result is an underutilized computer center charging its users high prices.

The point made by this illustration is that basing price on average costs, while having an intuitive appeal, can result in a disastrously counterproductive imbalance of supply and demand. The imbalance could result in either under- or overutilization of short run capacity. Only by fortuitous coincidence will supply and demand balance using this method.

2. Long Run Marginal Cost Pricing

Long run marginal cost pricing is based upon achieving the goal of maximizing net social benefit. [Ref. 12:pp. 239-240] The procedure here is exactly the same as the that described in Chapter III. Briefly restated, the goal is to balance supply and demand at that output level where demand equals LRMC. To achieve this, price is set at that level where D = LRMC. The precise rationale for this approach will

not be repeated here, but rather, the reader is referred to Chapter III for a more detailed description.

Essentially, while the *concept* of marginal cost pricing is well defined, obstacles exist which block implementation of the concept in any objective manner. A more detailed account of these obstacles is found in Chapter 4.

An additional drawback to this pricing method, not previously mentioned, should also be pointed out. Setting prices by this method will result in an imbalance between supply and demand in the short run. The price level arrived at by means of LRMC pricing (setting aside for now the previous objections raised as to the difficulty of achieving this) will achieve a balance between demand and LRMC. This balance between supply and demand will only exist for the short run situation corresponding to this ideal capacity.[5] Since the existing short run capacity, with its corresponding cost curves, will not equal this ideal capacity (except by fortuitous coincidence), the demand level corresponding to the price established by this method will result in either excess capacity or excess demand. An imbalance resulting in excess demand is illustrated in Figure 6.

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[5] The reader is referred to Chapter 3 for a more detailed explanation of these relationships.

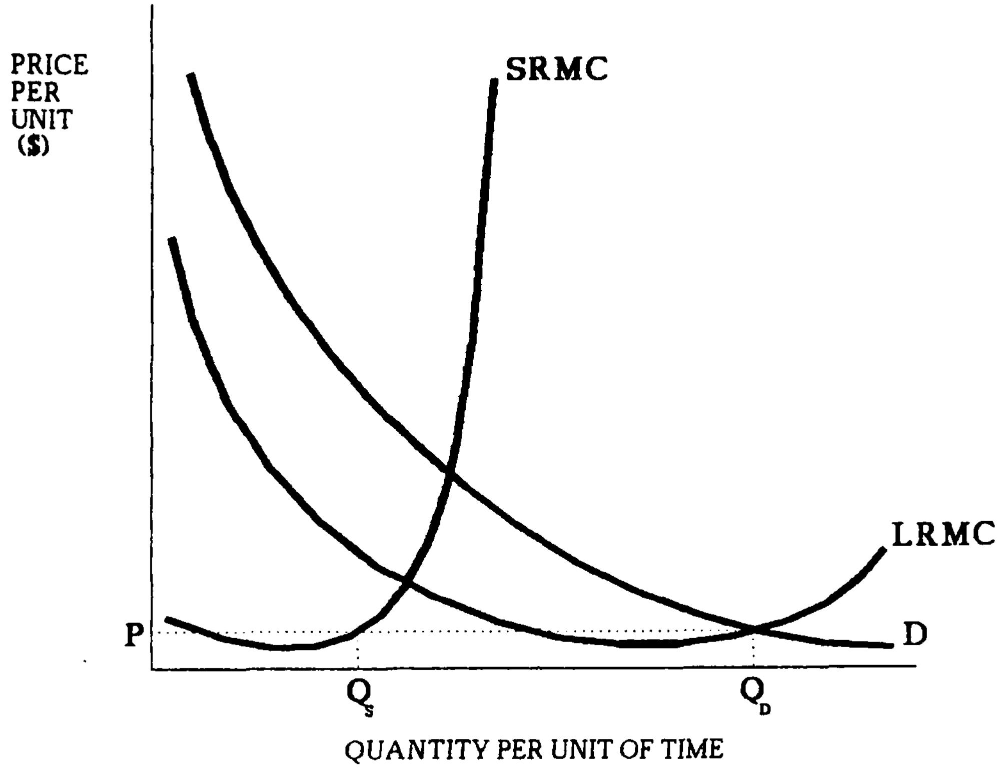

Figure 6. Short Run Excess Demand Created by Long Run Marginal Cost Pricing

However, the positive contribution of an imbalance created through setting prices in this manner is that feedback is provided indicating where ideal system capacity is located. If excess demand is experienced as a result of long run marginal cost pricing, then we can confidently deduce that system capacity should be expanded. Conversely, if system capacity is underutilized, then reduction of the system's size is called for.

3. Short Run Marginal Cost Pricing

This method sets prices where demand equals marg.nal costs of production with existing short run capacity. The

main benefit of using this approach is that a balance between existing capacity and demand will be achieved.

The drawbacks associated with this approach are many. Achieving a balance between short run supply and demand provides no information concerning what level the system should ideally be operating at in the long run. Managing the system so that user demand is equal to system capacity is certainly management's goal, but only insofar as that level of demand and system capacity approach the optimal level of operations. The overriding goal is to balance supply and demand where the greatest utility possible is provided by the system to its users. This pricing method is not capable of achieving this without additional information concerning LRMC and demand.

Furthermore, this method assumes that either a stable level of demand, or some means of storage for system products exists. If neither of these conditions applies, then the system will oscillate between periods of excess demand and underutilized capacity.

Lastly, as outlined in Chapter 4, quantifying demand and marginal cost is extremely problematical, rendering this approach impractical.

D. DEMAND-BASED PRICING

The pricing mechanisms which follow focus on fluctuations in demand for a particular commodity as a means to set prices.

1. Peak Load Pricing

The peak load pricing model was developed for products which cannot be stored (such as NTS capacity) and whose demand fluctuates with some predictability over time. This type of demand curve fluctuation typically results in an inefficient utilization of resources, i.e., either excess capacity if the system is sized to meet peak demand or unmet demand if the system is sized to meet average demand. During peak periods of demand resources may be strained, while during slack periods resources stand idly by.

The goal of the peak load pricing model is to discourage excess demand during peak periods and encourage demand during slack periods so as to create a more even, and hence efficient, pattern of resource utilization. Typically, this means establishing higher prices during peak periods as a means of shifting demand to lower priced off peak hours. [Ref. 13:p. 33] In the private sector, examples of peak load pricing include telephone rates, early bird specials at restaurants, etc.

While NTS demand during peacetime fluctuates predictably, this certainly would not be the case during periods of emergency or war. The inability to predict demand during these critical periods is the key drawback for applying this type of pricing by itself to the NTS. Actually, if demand fluctuates randomly, we would have to impose higher prices at all times because it would not be possible to

predict when the system might become congested. An additional demand distribution mechanism would also be needed for periods where demand fluctuates unpredictably.

2. Priority Pricing

If demand fluctuations are unpredictable, peak load pricing becomes impossible. Priority pricing schemes are used in this case. Under this pricing scheme, the mechanism for shifting demand to off peak periods is engaged only when demand actually approaches system capacity. This is accomplished by offering the user a variety of rates with the understanding that those services purchased at higher rates will take precedence over those purchased at lower rates, during periods of excess demand. This is not unlike the message precedence scheme currently employed except "precedence" becomes a function of price paid by the user. In the private sector, examples of priority pricing include first class mail, standby fares on airlines, etc.

The idea is that those users who will benefit the most from using the service at any given time will be most willing to pay the higher rates. In this manner, when system capacity is reached, the service will be self restricting to those users deriving the maximum benefit from system access. A balance is created when demand fluctuations are unpredictable. The most efficient use of the system at any given time is thus guaranteed. [Ref. 13:p. 188]

3. Congestion-Based Pricing

Congestion-based pricing is designed to create an equitable distribution of demand for service by charging on the basis of delay time caused by system congestion. During periods of excess demand, requests for service are placed in a queue. Charges are assessed based on the length of time spent in the queue. Obviously, higher charges will accrue during periods of peak demand. The idea is that users will tailor their requests for service based on utility gained versus perceived delay time costs. [Ref. 14:pp. 20-24] While not explicitly designed in this fashion, an example of this model is found in value added computer networks such as Genie or Compuserve. Periods of heavy system usage slow down system information throughput (i.e., it takes longer to transfer files, move around to the various network nodes, etc.), and since charges are assessed by the minute, users accrue higher charges for system use during periods of peak demand.

E. MARKET-BASED PRICING

Using this method, prices are set based upon observation of prices for similar goods or services available in the marketplace. This method is particularly attractive for industries with a ready availability of outside, competing services providing the same good and is practiced frequently in the private sector. [Ref. 11:p. 106] For example, a businessman opening a new restaurant would probably not

undertake any sort of economic analysis of his operating costs and expected customer demand in order to set prices on his menu. The most likely course of action would be to observe prices for similar items in comparable restaurants and set prices accordingly.

The obvious problem with this method is the inability to find a marketplace environment and set of services which even remotely resemble the NTS, and therefore, no models upon which to base NTS costs are found to exist.

F. CONCLUSION

A great deal of further study and analysis is possible with respect to the workings, advantages, and pitfalls associated with each type of pricing scheme mentioned. With this in mind, let us, nevertheless, consider each major category of pricing methods on the basis of the major features described above.

1. Cost-Based Methods

The recommendation is against using the cost-based methods for several reasons. First of all, average total cost pricing offers as its central quality the ability to recoup costs incurred in providing the service. This quality is not of any real advantage with respect to the goal of bringing user demand within system constraints. This would do little to alleviate excess demand on the system during peak periods. This method would reduce demand only to the extent that *any*

charge to the user would serve to reduce demand. Prices for system use might very well be much higher under this scheme than necessary to meet NTS demand management goals. As the computer center example pointed out, this pricing method could easily destabilize supply and demand with either under-or-overutilization of the system being the end result.

Neither short nor long run marginal cost pricing are practical alternatives given the extreme difficulty encountered in quantifying the requisite cost and demand parameters. Even if these problems could be surmounted somehow, additional problems remain. LRMC pricing would create an imbalance between supply and demand in the short run. These imbalances could only be avoided if system capacity could instantaneously be changed which, by definition in the short run, it cannot. Imbalances would continue to exist until the appropriate short run system configuration was in operation. This, in turn, might require large amounts of both time and money. The redeeming feature of this method is that it provides feedback allowing system managers to reliably determine whether system expansion or contraction is called for.

SRMC pricing promises to balance supply and demand only in the short run. It cannot serve as an aid in moving towards ideal system capacity. This method is also inappropriate in that NTS demand is not stable, and system capacity cannot be stored.

2. Demand-Based Methods

Demand-based methods redistribute demand more efficiently than cost-based methods, and also they carry the advantage of being *relatively* easy to formulate because determination of actual costs of operating is not necessary. Instead, the focus is shifted to determining the effect of price on the demand curve which is not simple by any means, but simpler than trying to untangle the complicated costs of operating the NTS.

Peak load pricing is most appropriate in an environment where peak usage periods can be predicted. This is certainly the case for the NTS in peacetime, but during times of emergency or hostilities this becomes difficult.

Priority pricing carries with it a number of advantages. If it is important to the originator of a message for that message to get through, then it seems that they ought to be willing to pay in direct proportion to that perceived level of importance. This type of scheme might also be piggy-backed on top of the already existing and widely understood message precedence system, thereby providing a relatively simple, well understood method of charging NTS users.

At the expense of simplicity, peak load pricing could also be superimposed onto a priority pricing scheme. This would provide the further benefit of more evenly distributing demand with respect to system capacity. Some of the burden experienced by communications centers late each day, and in

particular, late Friday afternoon, might be shifted to off peak hours in pursuit of reduced rates at those time. Obviously, this effect would occur only during periods where demand levels were predictable, e.g., peacetime, but this benefit is not insignificant. During periods of demand level volatility, e.g., wartime, the priority pricing mechanisms would still serve to guarantee optimal system utilization.

The congestion-based methods' demand distribution mechanism depends on the user's accurate perceptions concerning periods of congestion. Once again, as is the case with peak load pricing, this is reasonably predictable during peacetime only, but like peak load pricing, it might still prove useful anyway if used in conjunction with priority pricing. Between peak load and congestion pricing, peak load pricing is easier to understand and would certainly be easier to implement.

VII. RECOMMENDATIONS

A. INTRODUCTION

The purpose of this chapter is to assimilate the information provided in Chapters V and VI in order to form the basis for a set of general recommendations for the NTS with respect to demand reduction. Any recommendation made should only be as specific as allowed by the facts and analysis upon which it is based. The conclusions reached in the foregoing chapters are general in nature and are based largely upon facts painted with rather broad brush strokes. By necessity then, any recommendations to follow must retain this same general character.

In addition, several potential objections to the implementation of a pricing strategy are discussed. In response to the first, and most significant objection, a quick look at the Navy Fuel Allocation ystem is provided as an example of how this objection might be surmounted.

B. DEMAND BASED APPROACH

Chapter V concludes that a significant portion of message traffic handled by the NTS is of little or no value. From this we further conclude that, at the very least, demand reduction is in order. Chapter VI provides a review of the salient features inherent in potential pricing strategies.

Advantages and disadvantages attendant to each are discussed. Based upon the foregoing information the recommendation to pursue demand reduction via a demand-based pricing strategy is made. In particular, a priority pricing model seems most appropriate in that it does not require demand fluctuations to be predictable, and it might be superimposed relatively easily on the existing message precedence hierarchy. Priority pricing's chief advantage is that optimal use of system capacity is ensured at all times. The simultaneous addition of a peak load pricing mechanism would provide additional advantages resulting from a more even distribution of system demand, albeit at some cost to simplicity. Also, since the class of message traffic with the lowest value, to a large extent, deals with ineffecient use of collective addresses, the specific plan adopted should consider the number of message addressees when assessing charges (in addition to precedence level).

Obviously a much more detailed set of specifications is required before the first steps toward implementation could be made. The additional research and analysis to accomplish this, however, falls outside the scope of this thesis. This need might serve as the starting point for subsequent work seeking follow up on the ideas presented here.

C. POSSIBLE OBJECTIONS

1. Who Generates System Demand?

A pricing scheme raises the cost of entering a message into the NTS and thereby provides a means for controlling demand. This conclusion, however, is valid only if the costs of entering a message are actually being carried by those who originate the demand for NTS service, i.e., these who desire value from the service. What if the origin for NTS demand is not to be found with the message drafters who would be charged in a simple pricing scheme? If this were the case, then pricing messages would only serve to create a burden for message drafters and leave demand levels untouched.

One objection to pricing of messages asserts that the origin of NTS demand lies with those agencies or offices requiring that the message traffic be sent and not with the originators of the messages themselves. By application of the logic detailed above, establishing a pricing mechanism would have little or no effect on reducing demand. This argument recognizes that the bulk of messages in the system are sent because they have to be sent. They are sent in response to regulations, inquiries, or reporting requirements established at a level higher in the chain of command.

A single message from COMNAVSURFPAC requiring a monthly status report on damage control readiness training, for example, would generate thousands of messages in response, on a monthly basis, until the status report requirement is

either superceded or rescinded. Now then, which NTS users are generating the demand level represented by these thousands of messages? It appears that the total demand represented by these thousands of messages is actually created by COMNAVSURFPAC; however, in a simple pricing scheme they would only be charged for entering a single message into the system. The point is that demand is generated by those whom receive value from the message, and this is frequently the message receiver whose actions caused the message to be sent in the first place. This example illustrates how pricing might have no significant effect on controlling user demand unless prices are borne by those who receive value from the messages. In this manner, the overall ability of a simple pricing system to control user demand is seriously challenged. There are at least two ways of dealing with this which will be outlined further on.

2. Need for an Accounting System

Assuming that pricing of messages could control system demand, at least one other major potential objection to following this sort of strategy is seen to exist. In order to charge for NTS services, it is obvious that some sort of accounting system would be required to keep track of "customers" and their bills. Who used the service, when, and to what extent would have to be known in order to calculate the appropriate charges. A method of keeping users informed

of their accrued charges and tracking payments would also be required.

With the addition of two further observations the significance of this potential objection becomes readily apparent. First, an accounting system capable of accomplishing the sorts of tasks described above does not currently exist. Second, an accounting system of this type would probably be rather expensive to create owing to its requisite size and complexity.

D. NAVY FUEL MANAGEMENT SYSTEM: AN ANALOGY

If NTS demand, or a very large part of it, is ultimately generated by those agencies, offices, commands higher in the chain of command, and regulations requiring responses, then any pricing scheme can only be successful if the increase in costs can influence their behavior. Not only would pricing be ineffective in curbing demand, but it would impose an additional burden on NTS users. It does not seem fair to charge users for a service whose usage is required and that, therefore, they have no control over. Can this problem be circumvented, and if so, how?

One possible solution would be to somehow peg prices to the total number of messages, including required responses, which a message entered into the system generates. A plan of this sort, however, would be almost impossible to implement. How could one devise a method of looking at a message in order

to measure the number of responses it would require? Even if a method could be found, it is apt to be complex, poorly understood, and difficult to execute. This procedure would also be ineffective with respect to messages not sent in response to another message, but rather, in response to standing requirements and regulations.

Perhaps one method of implementing a pricing system whose enhanced cost effect is felt in full, even at the highest levels in the chain of command, would be to pattern it after the Fuel Management System used to allocate and account for fuel usage in the fleet. The situation with respect to fuel used in the fleet is analagous to the NTS and the extent to which its services are used by the fleet.

Fuel is a resource whose usage requires careful management. Demand for its use must be controlled. Any given ship is allotted a quarterly fuel "budget", i.e., a finite quantity, the use of which must not be exceeded. For the most part, the individual ship has no control over where it must be, how fast it must steam to get there, etc. In other words, a ship has little control over the factors which determine the amount of fuel it uses. The ship, nevertheless, is required to remain within its allotted budget. This seems very much like the situation where a ship would be charged for entering messages into the NTS yet it would have no control over the requirement to send the message. Control over that

requirement resides higher up in the chain of command as do the directives which control a ship's movements.

Now then, what feedback mechanisms exist in the Fuel Management System [Ref. 15] to control the overall use of fuel by the fleet? Control of total demand for fuel is maintained by a system which sets fuel allocations at various levels in the fleet command hierarchy all the way down to the individual units. Some finite quantity of fuel is given to CINCPACFLT annually, which is to be used to support fleet operations for the entire year. This pool is then allocated to Third and Seventh Fleets on a quarterly basis. Each fleet then further divides its allocation among the various Cruiser-Destroyer and Amphibious Groups which it in turn is responsible for. Within each Group, fuel is allocated among the squadrons, and then ultimately, each squadron allocates fuel to each of its individual ships.

At each step along the way the allocation amounts are set according to a planning procedure which focuses on tentative schedules, operational tempo, exercises, real world missions, various ship-type burn rates, etc. Conversely, planning procedures at every level in the chain of command operate within the constraints imposed by the amount of fuel available. In this manner, Fleet planners are able to achieve a balance between demand for fuel and available supply. An accounting procedure is in place which tracks actual fuel

amounts consumed and compares them against budgeted figures in order to monitor planning efficiency. [Ref. 16]

What if the same sort of procedure were established with respect to the supply and demand for NTS services? This would circumvent the objection raised concerning costs not being felt by the actual sources of demand. First, prices would be established for messages (for purposes of this illustration the exact pricing method applied is irrelevant). Based upon NTS capacity, a finite budget to be used for NTS services could be given to the Fleet Commanders. An allocation process similar to that used for fuel would then be applied in order to allocate slices of the budget all the way down to the individual unit level.

One difference between the two schemes is that while fuel is allocated by quantity, messages would more appropriately be allocated by use of a finite budget and pricing. The reason for this difference derives from the nature of the resource being allocated. Fuel can be stored over time and is homogenous in that one barrel of fuel is not different than another. Message traffic capacity, on the other hand, cannot be stored and is not homogenous in that messages vary in terms of length, and required speed of transmission. A set of prices set to reflect these differences with a total budget set to reflect system capacity, is the better way to reflect these differences.

Planners at all levels in the chain of command would be forced to balance the finite supply (i.e., NTS capacity) of communications resources against demand. Demand would have to be planned within the constraints imposed by the available budget. Pricing supplies the feedback mechanism for monitoring the effectiveness of communications planning. The total cost for messages, including the cost of required responses, would have to be considered by all levels in the chain of command under this plan just as fuel consumption by subordinates must be considered when ordering ship movements.

By manipulating prices and budget amounts, demand levels for NTS service could effectively be controlled. By attaching higher prices to message service the lowest value message traffic could be eliminated thereby eliminating the problems created by excess demand over short run capacity. Pricing could be used to effectively control demand.

Modeling NTS resource allocation after the Fuel Management System would require the creation of an accounting system to monitor message traffic service. The aforementioned problems concerning cost and complexity would remain. The question to be answered is whether a system can be devised cheaply enough so that the benefits gained from improved NTS efficiency are seen to outweigh the costs of creating such a system.

Another method perhaps simpler to implement, would be to include accounting codes, designating who is to be charged for replies, along with all messages requiring a response. This

technique would function very much like requiring the inclusion of a self-addressed stamped envelope along with each message requiring a reply. In this manner, the costs incurred by message replies are carried by those who receive value from them.

VIII. CONCLUSIONS

A. OVERVIEW

This thesis has attempted to accomplish a number of varied goals. Foremost among them is the explanation concerning excess demand over short run system capacity and the manner in which ideal system capacity is defined. Economic principles were used as the tools to accomplish this. Throughout, the perspective has been from the point of view of a manager of the NTS and the sorts of decisions which they would have to make to ensure efficient system operation.

The concept of ideal system capacity is well understood. The inability to translate this concept into any sort of practical, objective plan is of great concern to the NTS manager. The search for information of practical value led to a reexamination of the facts and principles applicable to the NTS situation. On the basis of this reexamination a hypothesis was formed that excess demand, including a relatively large number of low value messages included in its make-up, was caused by the extremely low cost imposed by the NTS on its users.

This conclusion was then subjectively validated by way of a judgmental survey collected from fleet personnel. On the basis of the survey results, demand reduction was advocated. Whether demand should be reduced to the bounds of present

short run capacity, or whether system expansion to some degree is also called for, cannot be decided on the basis of the information at hand. In any case, demand reduction is certainly called for as a step towards optimal usage of NTS capacity, short and long run.

What followed was a review of the salient characteristics of various pricing mechanisms in order to judge their appropriateness for adoption by the NTS. Demand-based methods are seen as superior to cost based, and key features of priority pricing, specifically, make this particular model appropriate for the environment within which the NTS operates.

Lastly, two key objections to any sort of pricing strategy were outlined. The first dealt with the inherent inability of prices to control demand within the NTS, and the second raised the issues of cost and complexity with respect to the accounting system that a pricing strategy would require.

A look at the Navy Fuel Management System provided a means of circumventing the serious problems raised by the first objection. The second objection's significance depends on the value attached to achieving efficient NTS operation.

Without any sort of demand management mechanism, the NTS is faced with two possible courses of action. The first is simply to stand by while demand increases and manage the resulting problems as efficiently as possible. The second is to respond to each demand increase with an increase in system

capacity. Historically, the second of these two alternatives has been followed.

Perhaps the most solid conclusion reached by the author is that the recommendations and findings of this thesis are only preliminary. Extensive follow on work is required before solid information usable at a "Monday morning action meeting" can confidently be provided to NTS decision makers.

B. AREAS FOR FURTHER STUDY

This thesis has attempted to cover a great deal of territory in a very short space. Much additional study remains in order to fully develop the ideas and arguments mentioned.

With respect to the starting assumptions, i.e., that demand exceeds NTS short run capacity, more work is required to quantify the precise nature of demand for NTS service and key contributing factors to excess demand. A complete statistical analysis concerning the breakdown of message traffic volume by originator, number and type of addressees, and general message subject trends would contribute towards a better understanding of how demand might best be managed. Also, to what extent is excess demand a function of an increase in the number or length of messages entered into the system?

In the realm of demand management methods, additional questions concerning the efficacy of administrative methods,

both past and future, to control demand require exploration. With respect to pricing methods a much more complete study concerning the operation, advantages, and disadvantages of each as they might be used by the NTS is required before a more detailed set of recommendations might be forwarded.

Another relevant question is what form might the requisite accounting system take in order to meet desired goals such as economy, efficiency, and simplicity?

Lastly, are the costs attendant to imposing demand management strategies excessive in light of potential technologies which might dramatically increase NTS capacity?

APPENDIX
JUDGMENTAL SURVEY RESPONDENTS

The following list details the persons, job titles, and/or qualifications, agencies, dates, and times for the telephone interviews conducted with participants in the judgmental survey.

Telephone conversation between Dr. El-Sabban, Operations Research Analyst, COMNAVTELCOM and the author, 22 January 1990.

Telephone conversation between Mr. David Johnson, Deputy Assistant Chief of Staff to the Director of Operations and Readiness, COMNAVTELCOM and the author, 23 January 1990.

Telephone conversation between Ann Carter, LT, USN, Assistant for Communications Automation, OPNAV 941h and the author, 23 January 1990.

Telephone conversation between Mr. Robert Scott, Assistant Communications Officer, NAVCOMMSTA Stockton, CA and the author, 1 March 1990.

Telephone conversation between Capt. Wirt Fladd, Commanding Officer, USS TARAWA (LHA 1) and the author, 1 March 1990.

Telephone conversation between M.H. "Buzz" Hoever, CAPT, USN (RET), Commanding Officer, NAVCOMMSTA Nea Makri, Greece, 1983-1985, Commanding Officer, NAVCOMMSTA Balboa, Panama, 1978-1981, and the author, 1 March 1990.

Telephone conversation between Mr. Bill Ayers, Supervisor, Traffic Analysis Section, NAVCOMMSTA Stockton, CA and the author, 5 March 1990.

Telephone conversation between Frank Green, LT, USN, Communications Officer, USS TARAWA (LHA 1) and the author, 5 March 1990.

Telephone conversation between Duane Coyle, LCDR, USN, Communications Officer, Cruiser Destroyer Group One and the author, 6 March 1990.

Telephone conversation between Paul Madursky, CDR, USN, Head of Current Operations, Communications Division, CINCPACFLT, Pearl Harbor, HI, and the author, 6 March 1990.

Telephone conversation between Quint Webb, LCDR, USN, Force Telecommunications Officer, COMNAVSURFPAC, San Diego, CA and the author, 19 March 1990.

Telephone conversation between Dan Seesholtz, LT, USN, Communications Officer, COMCARGRU 7, and the author, 20 March 1990.

REFERENCES

1. Maurice, S. Charles and Smithson, Charles W., Managerial Economics, 3d ed., Irwin, Inc., 1988.

2. DiMaggio, Kathryn A., Pricing As A Demand Management Tool For Record Communications, Master's Thesis, Naval Postgraduate School, Monterey, CA, March 1989.

3. Nicholson, Walter, Microeconomic Theory, 2nd ed., The Dryden Press, 1978.

4. Ein-Dor, Phillip and Jones, Carl R., Information Systems Management: Analytical Tools and Techniques, Elsevier Science Publishing Co., Inc., 1985.

5. Garrison, Ray H., Managerial Accounting, Business Publications, Inc., 1988.

6. Peterson, Douglas R., Naval Communications, Master's Thesis, Naval Postgraduate School, Monterey, CA, September 1988.

7. Jussawalla, Meheroo and Lamberton, D. M., Communication Economics and Development, Pergammon Press Inc., 1982.

8. Deming, William E., Some Theory of Sampling, John Wiley and Sons, Inc., 1950.

9. Series of telephone interviews conducted by the author between 22 January and 6 March 1990. Complete reference to these interviews found in Appendix.

10. COMNAVTELCOM Washington DC Naval Message, Subject: Publication Corrections to NTP 3 (G) and NTP 4 (C); Identification of Operational Messages, 272025ZDEC 89.

11. McFarlan, Warren F. and McKenney, James L., Corporate Information Systems Management: The Issues Facing Senior Executives, Richard D. Irwin, Inc., 1983.

12. Yordon, Wesley J., "Telephone Rates: Economic Theory and Current Issues," in Telecommunications: An Interdisciplinary Text, ed. Lewin, Leonard, Artech House, Inc., 1984.

13. Crew, Michael A. and Kleindorfer, Paul R., The Economics of Public Utility Regulation, The MIT Press, 1986.

14. Dolan, Robert J., Priority Pricing Models for Congested Systems, Doctoral Dissertation, The University of Rochester, Rochester, NY, 1976.

15. Greene, Robert L., Welfare Economics and Peak Load Pricing, University of Florida Press, 1970.

16. Commander Naval Surface Force Pacific Instruction 9261.1A, Fuel Management System, February 1990.

17. Telephone conversation between LT Tony Harnett, N323, Force Fuels Officer, Naval Surface Force Pacific and the author, 6 February 1990.

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10.	Commander, Naval Telecommunications Command ATTN: Dr. El-Sabban 4401 Massachusetts Avenue, N.W. Washington, DC 20390-5290	1

11. Commanding Officer 1
Naval Communications Station
ATTN: LCDR Kathryn A. DiMaggio
Jacksonville, FL 32212-0030

12. Commanding Officer 1
USS TARAWA (LHA 1)
FPO San Francisco, CA 96622-1600

13. Commanding Officer 1
US Naval Communication Area
Master Station WESTPAC
FPO San Francisco, CA 96630-1800

14. Commanding Officer 1
US Naval Communication Area
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Norfolk, VA 23511-6898

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US Naval Communication Area
Station EASTPAC
Wahiawa, HI 96786

17. Commanding Officer 1
Naval Communication Station Stockton
Stockton, VA 95203

18. LT J. DeLeeuw 2
Department Head Class 114
Surface Warfare Officers School Command
Naval Education and Training Center
Newport, RI 02841-5012